Generating Trigger Primitives from an EIC Electromagnetic Calorimeter

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Background

- Virtually every modern calorimeter readout continuously samples the detector signals
- The depth of storage in the front-end determines the trigger latency when a decision has to arrive (e.g. 10MHz, 1000 samples -> 100μs)
- Derive trigger primitives from the front-end to distribute the main workload to FPGAs
- Collect primitives to contribute information to overall trigger decision (L2, L3)
- Example: sums of overlapping 2x2, 3x3 emcal towers to store the highest value (or *n* such values)
- That leads up to a "trigger-less" readout system in the future (e.g. LHCb-style) with "front-end support"

Trigger Primitives

- sPHENIX has already demonstrated the feasibility of generating trigger primitives in the front-end system of an electromagnetic calorimeter
- trigger on collisions with particular properties and signatures, such as high-p_T clusters, or
- signatures from mesons decaying into photons or e+e−, such as π^0, η, or Υ

Technology Choice

- Start with well-known technology − the ATLAS/sPHENIX FELIX board
- Multi-million $ development effort that we tap into for ~$20K
- High-end Xilinx Kintex UltraScale FPGA at its core
- FELIX has 46 (of 48 max) usable high-speed 10GBit/s duplex transceivers, scope of up to 4400 channels (e.g. a 66x66 calorimeter array) at 100's of KHz input
- Note: the main role of FELIX in sPHENIX is the streaming readout of the TPC and the MAPS silicon tracker (candidates for EIC tracking detector)
- Same Design will be in use for ATLAS/LHCb/ALICE running in 2023++

This funding request…

- … derives from both sPHENIX high-speed EmCal and TPC readout technologies and experience
- …has synergy with ongoing development work in the sPHENIX orbit (est. 70% overlap, drivers, DAQ technology, etc)
- … leverages existing EmCal expertise, existing datasets, and hardware (and a DAQ system already in widespread use in EIC R&D)
- … involves hardware (principally the card + host PC), training (to attract grad student/PD), and labor/some travel

Key Points

- PCIe or fiber data path for trigger output ("PCIe is the new high-speed bus for experiments")
- Using actual EmCal prototypes available with cosmics or beam, but also generate simulated patterns to feed to the trigger processor
- We also have plenty of test beam data that can be re-generated as input to the card (or a CPU to cross-check)
- Well-known calorimeter Digitizer boards could be borrowed for some time to get started
- Lots of experience available with FELIX card

Who we are

- John Kuczewski − electronics engineer, main developer for FELIX in sPHENIX
- Craig Woody − Emcal and other detector expert, and expert in more things than can fit here
- Sean Stoll − Emcal, electronics, SiPMs,…
- Martin Purschke (PI) − sPHENIX DAQ manager, readout, computing, networks, electronics, software, VHDL,…

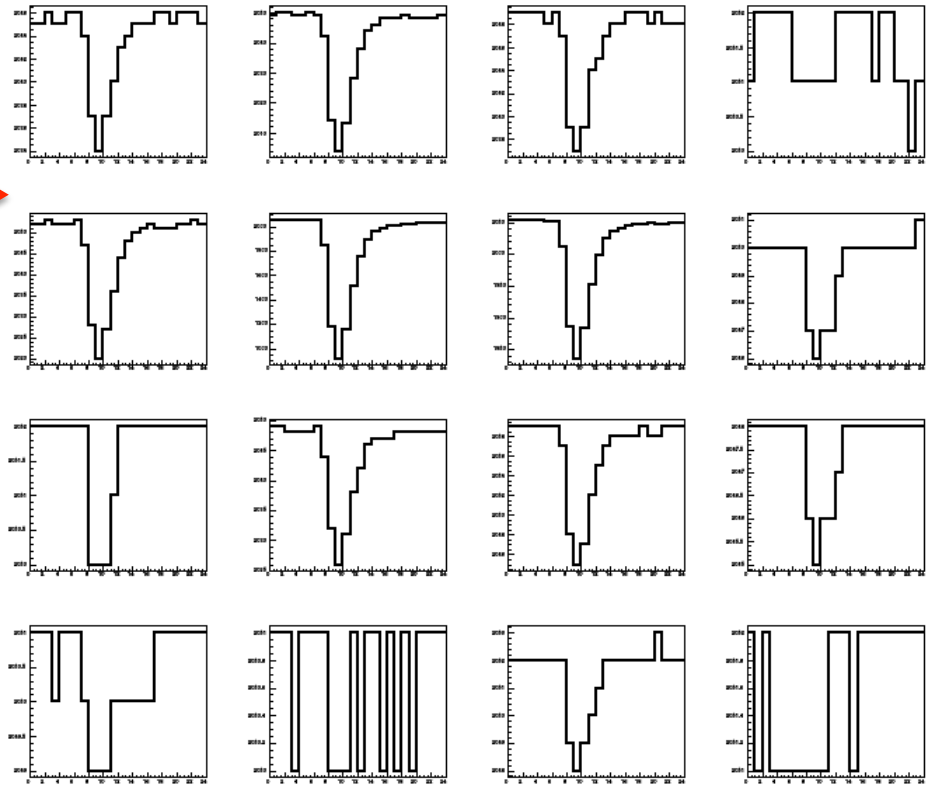
Benefits

- Demonstrates feasibility of a large-scope (o(4000) module) fast front-end data processor for trigger primitives
- Learn how to best *assist* a potential trigger-less readout with primitives
- Develops experience for such a trigger-less readout
- Trains student/PD with valuable skills (FPGA-VHDL/DAQ/etc)
- Immediate/short term: improve the quality of test beam data and cosmics data for EmCals and other detectors (events not on a fixed clock - anti-aliasing w/ free-running clocks)

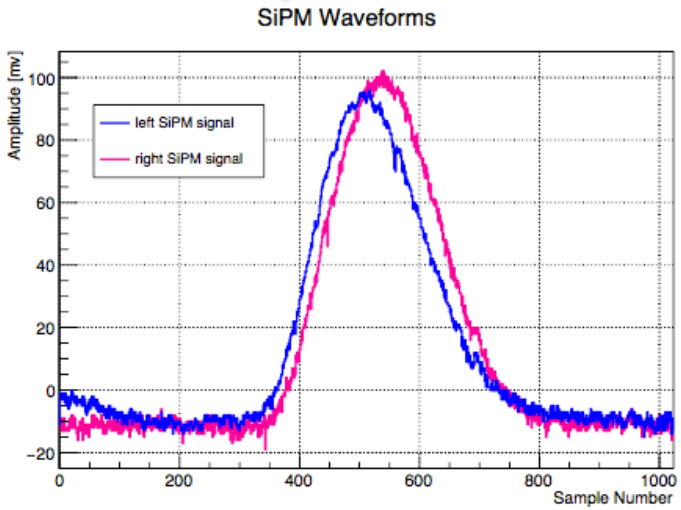
Existing Datasets

Existing SiPM waveform data from several Fermilab Test Beams (60MHz sampling)

Shown here is a 4x4 sweet-spot out of a 8x8 tower array



2GHz sampled test beam data also available

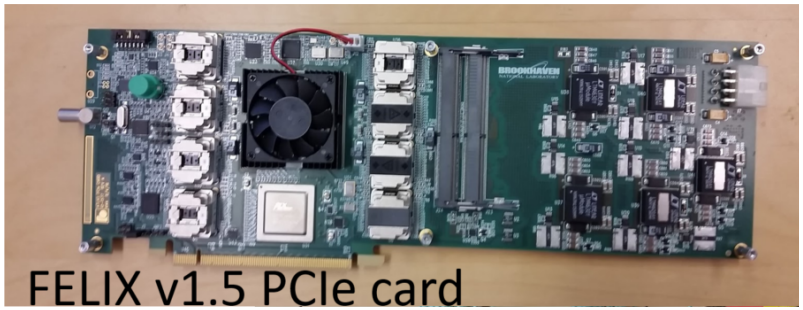


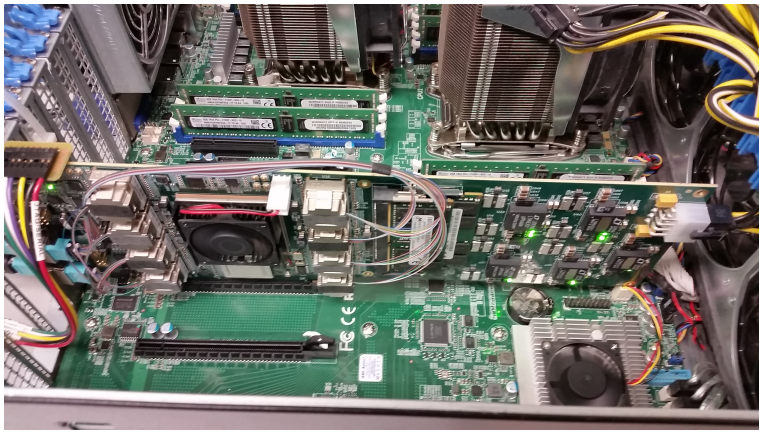
Plan to feed “canned” EmCal response to Felix

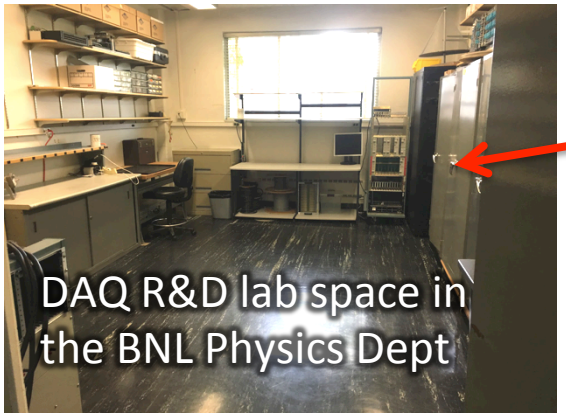
Reproducible input to test algorithms and speed, also compare to CPU

Mr Felix

- The FELIX card is the single biggest line item in our request, and at the core of the proposal


FELIX v1.5 PCIe card




DAQ R&D lab space in the BNL Physics Dept

This is the space that I'm already working on FELIX with the expert engineer

Self-triggering/Streaming readout

- The “next big thing” in DAQ-land
- Being considered for actual Collider running (too early to call, but a streaming-readout TPC is part of every proposal)
- Extremely useful for all test beams and calibration tasks where signals are not on a fixed clock
- The immediate benefit is for most ongoing and future R&D efforts

Activities/Deliverables

Activity	Q1	Q2	Q3	Q4
Procure a FELIX card and host system	x			
Implement the FELIX readout in RCDAQ	x	x		
Select and procure a digitizer front-end card	x	x		
Develop the FPGA and CPU code		x	x	x
Test the system and characterize the performance		x	x	x
Final report				x

Deliverables	Q1	Q2	Q3	Q4
Demonstrate a commissioned development system			x	
Report obtained performance parameters				x
Final report				x

Funding Request

Funding Request	Amount
FELIX Card and host system	$22,000
2 Digitizer cards	$5000
Programming course	$3000
1/2 post-doc for 1 year	$36,000
Total	**$66,000**

I said we can borrow the digitizers. This $5K is for getting on board parasitically with our next Fermilab test beam

Virtually no other cost, FNAL test beam typically costs >$200K, a real bargain

Summary

Very cost-effective way to develop and demonstrate the generation of trigger information in the front-end system of an electromagnetic calorimeter

Get signatures from mesons decaying into photons or e+e−, such as π^0, η, or Υ

Assist a potential trigger-less system with front-end information

Use a high-performance, cutting-edge hardware platform

Leverage existing work, expertise, datasets

Opportunistically participate in FNAL test beam if desired

Train a student or post-doc with extremely valuable skills

Bottom line: $66,000…